Application No. 09/815,816
Amendment Date April 13, 2004
Reply to Office action of March 16, 2004

Amendments to the Specification

Please replace paragraph [0058] (under section 2.1.2.1 in pages 16-17 of the original specification) with the following amended paragraph:

[0058] The noise removal step removes the noise in the image. The noise can be additive noise, spikes, or patterned noise of irrelevant patterns. The noise removal process is accomplished by linear low pass filtering, median filtering, or morphological filtering. In a preferred embodiment of the invention, directional elongated morphological filters are used for noise removal. From the structure of the possible marks, the direction and size of the directional elongated morphological filters can be derived. By chosing the proper structuring element for the feature extraction processing sequence, structure-guided feature extraction can be efficiently accomplished. In a preferred embodiment of this invention, features of different structures are extracted using directional elongated structuring elements. Directional elongated structuring elements have limited width in one of its dimensions. It can be efficiently implemented in a general-purpose computer using the methods taught in co-pending U.S. Patent Applications entitled "U.S. Patent Application Ser. No. 09/693723, "Image Processing System with Enhanced Processing and Memory Management", by Shih-Jong J. Lee et. al., filed October 20, 2000 and U.S. Patent Application Ser. No. 09/692948, "High Speed Image Processing Apparatus Using a Cascade of Elongated Filters Programmed in a Computer", by Shih-Jong J. Lee et. al., filed October 20, 2000. The direction of the elongated structuring element is chosen to be approximately orthogonal to the primary direction of the features to be extracted. The process works even if the input edge is slightly rotated. Also, directional elongated filters can be applied on any orientation according to the needs to preprocess for particular mark characteristics. In Figure 5 it is assumed that the mark image has dark elements. If this is not the case, the image can be inverted before pre-processing. The processes of Figure 5 can be applied in any direction and can be reapplied in multiple directions to filter for all expected elements of the mark. In an application, the first directional elongated closing operation 5202 reduces the noise

in the mark image by eliminating small dark extraneous image noise. The directional elongated closing residue operation 5204 enhances the mark and brightens the retained elements. The next directional elongated closing operation 5206 fills in the bright image elements. The last directional elongated opening 5208 reduces the noise in the background. The output image of the mark 5210 has bright image detail and only contains portions of the mark that are aligned with the structuring elements in 5202, 5206, 5208. The original image is processed by this method for each principle axis having elements important to the overall mark characteristics.

Please replace paragraph [0060] (under section 2.1.2.2 in page 17 of the original specification) with the following amended paragraph:

[0060] The segmentation step is done by thresholding the output image of the noise removal module 1000 (Figure 6). The thresholding method can be a simple global thresholding or local thresholding based on the neighboring pixel values. The method used in the preferred embodiment is the global thresholding method 1004 as shown in Figure 6. In Figure 6, the threshold value is

$$\text{Threshold} = \alpha * \text{maximum pixel value} + (1-\alpha)*\text{median pixel value}$$

α can be any value between 0 and 1 and the maximum and median pixel values are for image pixels 1000 within the operating area of the mask image. The threshold value T is compared to the image value A in step 1006. The mask input 1002 is the mechanism for region exclusion and indicates the mask output from the previous detection sequence. The delay element 1001 (Figure 3) provides the mask for the previous detection sequence. 0 = blocked, 1 = operating. The input 1000 is the output of the noise removal block 5102 which is a particular directional portion of the mark that is indicated as bright. The output 1008 is a segmentation of the remaining portions of the mark (working sequentially for detection) having the filtered direction.

Please replace paragraph [0073] (under section 2.1.2.6 in pages 19-20 of the original specification) with the following amended paragraph:

A3

[0073] The process of mark type classification 5110 is shown in Figure 9. In Figure 9, the first step is feature extraction 5402 followed by the classification step 5404. Because the structures of different mark types are different, the extracted features may include the shape features that span the range of characteristics for the marks that are true possibilities such as the curvature of an arc, direction or intersection angles of lines, and the relations among geometric entities such as the relative position and/or the relative angle between lines and arcs. Other features can be derived from the projection of detected marks to the symmetry axes. Another such useful feature is projection of the filtered image inside the detected portion of the mark in the direction of processing by the elongated filters. The angle of the symmetric axes can also be a good feature. From these features, the classification step 5404 determines the type of the mark <u>output 5406</u>. The classification step can use parametric or non-parametric classifiers to classify the mark.

Please replace paragraph [0087] (page 23 of the original specification) with the following amended paragraph:

A4

[0087] In this embodiment the process of learning mark line width is applicable to many different marks and the principles taught can be applied to features of the marks besides line width. The value Threshold_Value is set to 0.75 as a stop criterion. The Threshold_Value could be set to other values derived from training and selected by the designer. Max_Size is set to13 based in this example on the maximum line width of about 27 pixels. Max_Size could be set to other values derived from training and selected by the designer. The m[i] is calculated using the process shown in Figure 10. Note the explanatory relationship between Figure 11 and Figure 10. Figure 11 explains the processes that are integrated together in Figure 10. The processes 2401, 2402, and 2442

A4 cont'd

are pre-processing as described in 5002. The upper half of Figure 10 is a process for horizontal line segments wherein for explanatory purposes 2404 corresponds with 5004, 2424 with 5012, 2406 with 5003, 2422 with 5011, 2408 with 5006, 2446 with 5007, 2420 with 5010, 2410 with 5008 and the bottom half of Figure 10 is for vertical line segments wherein for explanatory purposes 2426 corresponds with 5004, 2440 with 5012, 2428 with 5003, 2438 with 5011, 2430 with 5006, 2448 with 5007, 2436 with 5010, 2434 with 5008. In this particular embodiment, a common part of the pre-processing operation is a 3X3 morphological opening to remove spike noise. The directional elongated processing includes a closing operation of 21X1 to pre-process the horizontal line segment and the 1X21 closing operation to pre-process the vertical line segment. Referring now to Figure 11, we see that pre-processing filters the input learning image of the mark and prepares it for measurement leading eventually to a learned size. Following pre-processing, two different sized closing operations 5004 and 5012 are performed on the pre-processed learning image to compute a difference image between the two results 5011. This difference image is weighted using the closing residue image 5007 through a process of weighting that emphasizes the region of the gray scale image containing the essential information needed to draw conclusions about (in this case) the mark line width (either horizontal, as shown in the top half of Figure 10 or the vertical as shown in the bottom half of Figure 10).

Please replace paragraph [0092] (page 24 of the original specification) with the following amended paragraph:

A5

[0092] The average of the closing residue image 5006 is also computed to normalize for image contrast variability. The normalization occurs through a ratio process 5008 to produce an intermediate result. The resulting m(i) 2416 of operation is the maximum 2414 of the intermediate result values of the operation for horizontal 2432 and vertical line segments 2412. Using m(i) the learning process iteration can be completed to converge on a learned line width.

Please replace paragraph [0094] (under section 2.4, pages 24-25 of the original specification) with the following amended paragraph:

[0094] Figure 5 shows the general approach to noise filtering using directional elongated filters to pre-process images. This general guidance is combined with the learned attribute in a particular embodiment. For this embodiment, Figure 8 shows the mark type in the image that is pre-processed. In this mark, the lines are all identical width, the principal elements of the mark are oriented generally horizontal or vertical, and the overall mark outer dimensions are greater than 200 pixels. Images of the mark are used in a learning process to determine s, a parameter related to line width. Two pre-processing filters are created as shown in Figure 12A for horizontal structures and Figure 12B for vertical structures. The input image 100 is assumed to be dark lines. If this is not the case, the image is inverted before being applied to these filters. The initial closing with a directional elongated filtering element 402 cleans up off axis dark noise in the image. The closing residue of the filter 404 uses the learned attribute of line width to clean the mark elements and produces a bright image output. Another directional elongated structuring element is used 406 to fill in the gaps in the bright image of the mark elements followed by another elongated directional structure opening 408 to clean up residual bright noise (dark lines in the original image). The output 410 is a bright image of the lines in the mark that are aligned with the elongated structuring elements of the filter which in this example are horizontal. A complementary process is shown in Figure 12B for the vertical portions of the mark. The initial closing with a directional elongated filtering element 412 cleans up off axis dark noise in the image. The closing residue of the filter 414 uses the learned attribute of line width to clean the mark elements and produces a bright image output. Another directional elongated structuring element is used 416 to fill in the gaps in the bright image of the mark elements followed by another elongated directional structure opening 418 to clean up residual bright noise (dark lines in the original image). The output 420 is a bright image of the lines in the mark that are

Ale

Application No. 09/815,816
Amendment Date April 13, 2004
Reply to Office action of March 16, 2004

aligned with the elongated structuring elements of the filter which in this example are vertical.